# **Optical Detection and Assessment of the Harmful Alga, *Karenia brevis***

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## LONG-TERM GOALS

Our overall hypothesis is that populations of the red tide species *Karenia brevis* give rise to distinct and identifiable optical signatures in inherent optical properties and remote sensing reflectance. Accordingly, the primary objective of this project is to refine and evaluate optical approaches to detect and assess bloom events of K. brevis, and to define limits of detection.

## OBJECTIVES

Specific objectives of this research include the following:

1) Measurements of inherent and apparent optical properties will be conducted in areas frequented by *Karenia brevis* bloom events off the west Florida coast, and attempt to identify key optical indices for discriminating blooms of K. brevis from other phytoplankton and other sources of optical variability.

2) We will examine the utility of inversion methods to retrieve phytoplankton absorption from reflectance, and subsequently evaluate this with regard to optical criteria for detection of *K. brevis* and other phytoplankton taxa.

## APPROACH

The funded research will address the following tasks:

*Task 1: Conduct measurements of multi-spectral and hyperspectral inherent and apparent optical properties in Florida shelf waters in and around regions impacted by bloom events of Karenia brevis.* Discrete profiles of the inherent optical properties will be assessed with a bio-optics package. This package may include a WETLabs Inc absorption/attenuation meter (ac-9), HOBILabs Hydroscat-6 backscattering sensor, and a suite of Satlantic radiometers (including a hyperspectral tethered

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14. ABSTRACT
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radiometric buoy). We have also successfully deployed a 100 spectral channel WETLabs, Inc. Hi-Star absorption/attenuation meter for determination of particulate and dissolved absorption, and this instrument is available for use on this project. Measurements of particulate backscatter may be made using three different instruments, the HOBI Labs, Inc. a-beta, a HOBI Labs, Inc. Hydroscat-6, and a WET Labs, Inc. ECO-VSF3. High spectral resolution surface remote sensing reflectance may be acquired using a Satlantic Hyperspectral Tethered Remote Sensing Buoy (HTSRB). In addition, a Satlantic MicroPro profiling radiometer will be used to provide profiles of upwelling radiance and downwelling irradiance, and can also be used to provide an independent measure of remote sensing reflectance.

Field operations will be conducted in late fall of years 2 and 3. If possible and should a bloom event occur, field measurements will also be conducted in year 1. The sampling will involve a flexible adaptive sampling style, to respond accordingly to often-unpredictable red tide events. To the extent possible, sampling efforts will be coordinated with the ongoing regional red tide efforts in the area.

*Task 2: Examine the utility of inversion methods to retrieve phytoplankton absorption from hyperspectral reflectance, and evaluate with regard to optical criteria for detection of K. brevis and other phytoplankton taxa.*

We intend to conduct a comparative investigation of inversion methods for retrieval of pigment absorption from reflectance. These include an algorithm currently under development by Schofield's lab and the decomposition algorithm of Lee et al. (2002). This latter approach utilizes a quasi-analytical algorithm to analytically calculate the particle backscattering coefficient and the total absorption coefficient from measured remote-sensing reflectance. The algorithm has been shown to work well in coastal waters, and retrieve pigment absorption spectra that differ in correspondence with the type of phytoplankton present.

## WORK COMPLETED

This project is in its initial stages, but a project website has been established ( ) and the co-PIs have initiated planning for project activities. A cruise off west Florida is scheduled for 3-7 November 2003 on the R/V *Suncoaster*. This cruise will be conducted in conjunction with Schofield's AUV project. Laboratory experiments to determine inherent optical properties of *K. brevis* are planned for early in 2004 at Mote Marine Laboratory. A University of Southern Mississippi Ph.D. student, Kevin L. Mahoney, graduated in August 2003. His dissertation research contributed to this project and manuscripts based on this work are being prepared.

## RESULTS

An analysis was conducted of a times-series of hyperspectral absorption data that had been acquired using a WETLabs, Inc. Hi-Star during a *Karenia brevis* bloom event off west Florida in October 2001. The data were analyzed using the similarity index method as described by Millie et al. (1997). The similarity index represented the degree of similarity between the observed total absorption spectrum measured with the Hi-Star and an average spectrum for *Karenia brevis* determined by microphotometry on single cells (Lohrenz et al., 1999) in the same population. There was a weak, but significant correlation between similarity index and cell concentrations of *K. brevis* as determined by microscopic enumeration (Figure 1). These results show promise for the potential use of in situ hyperspectral instrumentation to detect and monitor bloom events.

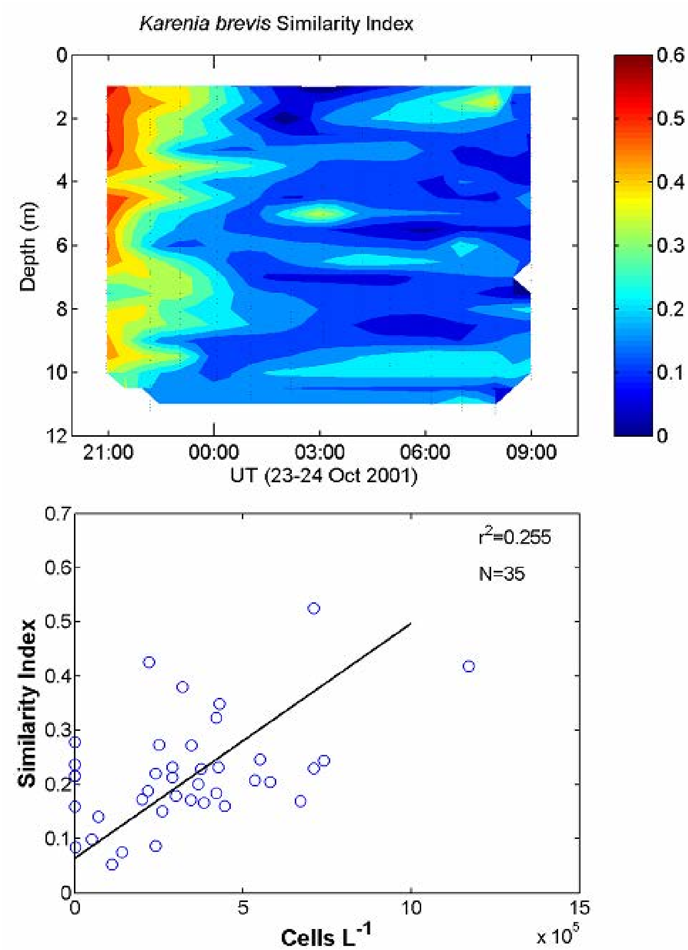


***Figure 1. Upper panel: A time-series of similarity index (SI) analysis of total absorption measured using a WETLabs, Inc. Hi-Star shows high variability over depth and time. An average spectrum determined for single cells by microphotometry was used as a reference spectrum. Lower panel: There was a weak but significant correlation ($r^2$=0.255, N=35) between SI determined from the Hi-Star data and cell concentration determined from microscopic enumeration of discrete samples.***

Forward modeling of reflectance using the radiative transfer model, Hydrolight 4.1, has been performed for a variety of cell densities of *K. brevis* (Figure 2, upper panel), in order to examine how variations in *K. brevis* abundance and distribution influence reflectance signatures. In waters dominated by *K. brevis*, there appears to be a distinct and consistent reflectance signature. Additional modeling efforts have begun to examine how these results are influenced by the presence of other optical constituents such as chromophoric dissolved organic matter (Figure 2, lower panel). These results will help efforts to utilize above water radiometric measurements as a means of detection and characterization of *K. brevis* blooms.

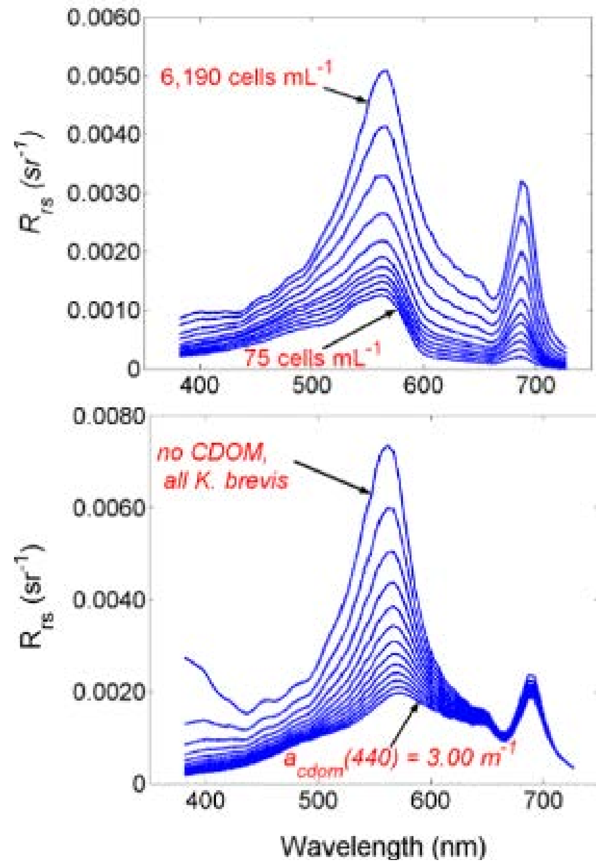


***Figure 2. Upper panel: The magnitude and shape of modeled reflectance spectra changed when the particle density of K. brevis was varied. The particle densities were varied from 75 (bottom spectrum), 250, 425, 600, 900, 1150, 1550, 2300, 3100, 4600, and up to 6190 (top spectrum) cells mL$^{-1}$. Lower panel: The reflectance signature of K. brevis was dampened as concentrations of chromophoric dissolved organic matter (CDOM) were increased. The absorption coefficient of CDOM at 440 nm was varied from 0 (top spectrum) to 3.00 m$^{-1}$ (bottom curve) in increments of 0.25 m$^{-1}$. The exponential decay slope of CDOM was 0.0175. The particle density of K. brevis was 6.2 x 10$^{3}$ cells mL$^{-1}$.***

One approach that has shown promise for using hyperspectral reflectance to classify algal bloom taxa involves the application of the Lee et al. (2002) inversion model. This quasi-analytical algorithm retrieves a unique phytoplankton pigment absorption signature from hyperspectral reflectance. Comparisons between retrieved and measured phytoplankton absorption showed good agreement (Figure 3). This provides a promising new approach for discriminating phytoplankton taxa using hyperspectral remote sensing reflectance.

## IMPACT/APPLICATIONS

An anticipated product of this effort will be the development of improved optical approaches for detection of *K. brevis*, and potentially of other algal taxa, that may be applied to observations made using moored or ship-deployed instrumentation, autonomous vehicles, or satellite or aircraft remote sensing.

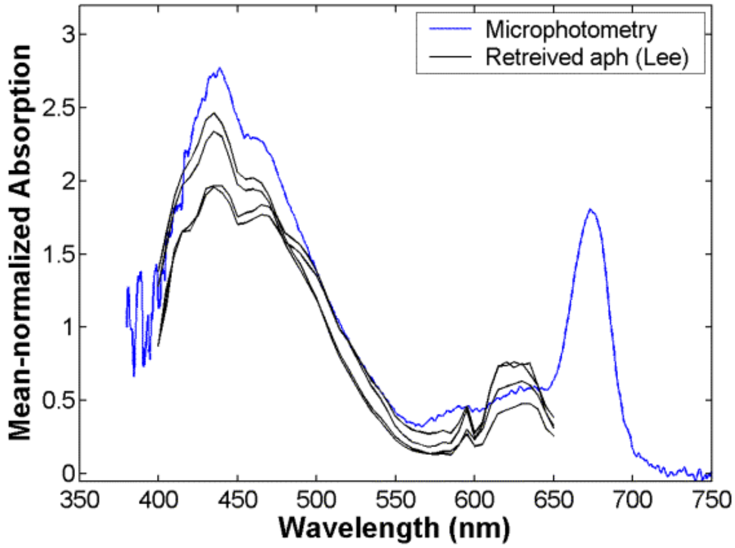


***Figure 3. Phytoplankton pigment absorption was retrieved from hyperspectral remote sensing reflectance measured during a Karenia brevis bloom in west Florida shelf waters using the algorithm of Lee et al. (2002). The results showed good agreement with absorption measured by microphotometry on single cells of the same population.***

## RELATED PROJECTS

This ONR-funded project is closely coordinated with another project funded by the NASA Oceanography Program in the Office of Earth Science (S. E. Lohrenz and G. L. Kirkpatrick, co-PIs). As part of the ONR Mine Countermeasures program, Schofield and other Rutgers investigators will deploy optical gliders equipped with sensors for hyperspectral absorption (Brevebuster capillary waveguide absorption meter), backscatter at two wavelengths and attenuation at one wavelength (WETLabs, Inc. SAM). Deployment of Remote Environmental Measuring UnitS (REMUS) autonomous vehicle equipped with a similar suite of optical sensors is planned by M. Moline (Cal Polytech) as part of his ONR Young Investigator project. These research efforts will result in AUVs flying a series of transects in the late fall off Sarasota, Florida through 2004. Support for overflights with a state-of-the-art hyperspectral airborne sensor (PHILLS-2) is also being sought by the Florida Environmental Research Institute.

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## PUBLICATIONS

Mahoney, K.L., 2003. Backscattering of light by *Karenia brevis* and implications for optical detection and monitoring. Ph.D. Thesis, The University of Southern Mississippi, Hattiesburg, MS, 135 pp.